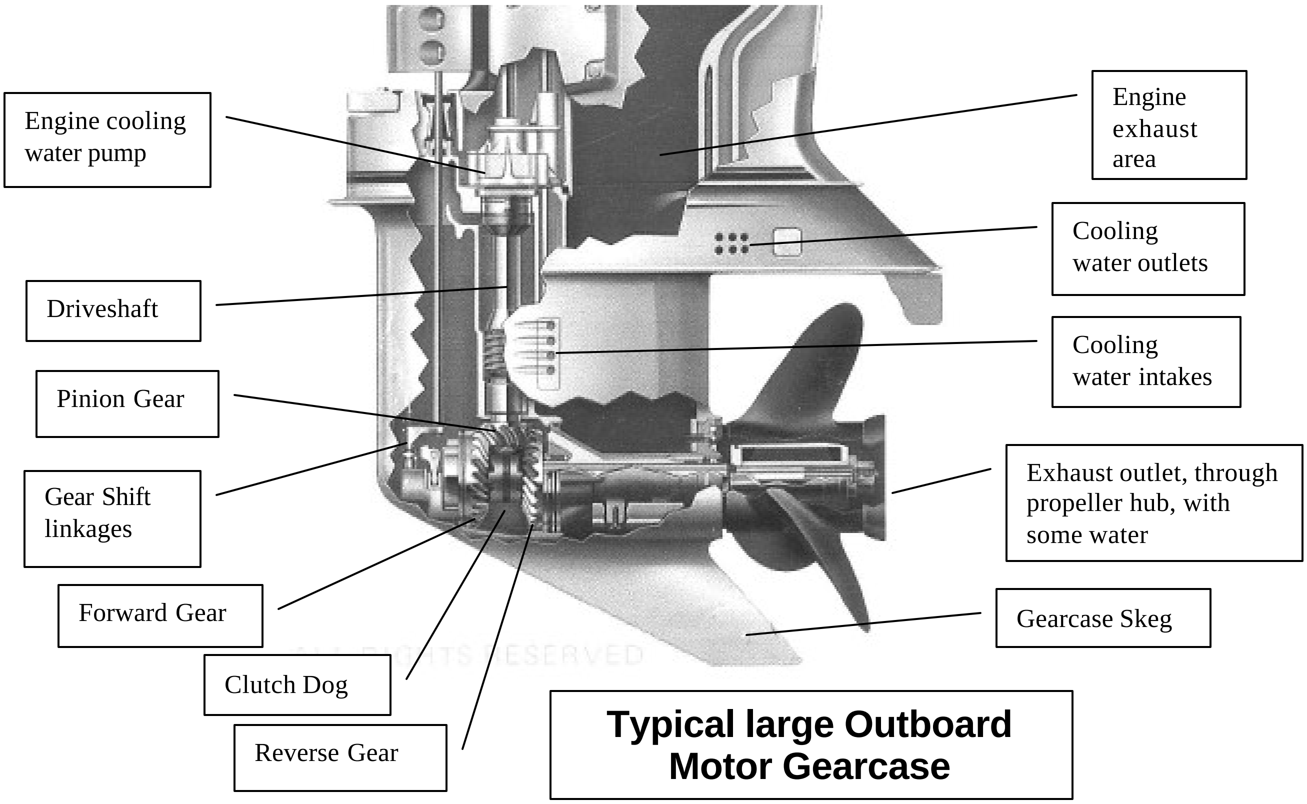
Outboard Transmission Diagnosis



Typical large Outboard Motor Gearcase

The outboard motor gearcase (or lower unit as it is sometimes called) does not look all that complicated, at least from the outside. However, when you consider what it does you'll soon see there are plenty of challenges (of the character building kind) awaiting the unwary technician.

The gearcase takes engine torque, multiplies it through reduction gears and then turns it 90 degrees to the propeller. It also must take the full propeller thrust and transmit it, via the midsection, into the hull.

The gearcase also contains portions of several engine systems, like the cooling system (water intakes, outlets, and water pump), along with the final portion of the engine's exhaust system.

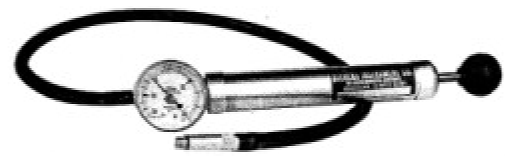
It also is the rudder for steering the boat and must be a slippery shape of minimal size to reduce drag and provide an undisturbed water flow to the propeller. And if all that's not enough, it also has to be completely water tight (to keep the oil in and water out of the oil), and be able to take engine's full throttle power all day if required with just one litre (or less) of gear lubricant.

As you can imagine with this many sometimes conflicting requirements involved, there's some intricate technology in most outboard gearcases. And naturally enough, quite a few special tools and techniques needed. That's the proper domain of service or workshop manuals and we'll leave that data to them, and deal here instead with the sorts of problems service technicians are likely to find, but not in the service manual.

Water in the oil

Draining the gear oil and checking its condition is part of just about every outboard service. It needs to be changed on a regular basis as the additives get "used up" by pressure and heat, and the oil's condition tells you a lot about what's going on inside. What do you do when the oil comes out all milky creamy/white in colour? That’s a sure sign of water mixed with the oil. If the motor's been languishing in the shed for a while, the water and oil will probably be separate, the water coming out first.

If there's water in the oil you know it requires some repair work, but resist the urge to tear it down immediately. Finding out where the water gets in (so you can fix the root cause) can actually be much more difficult after it is in pieces. And there's nothing worse than rebuilding a gearcase only to have it fail a pressure or vacuum test after all your hard work.



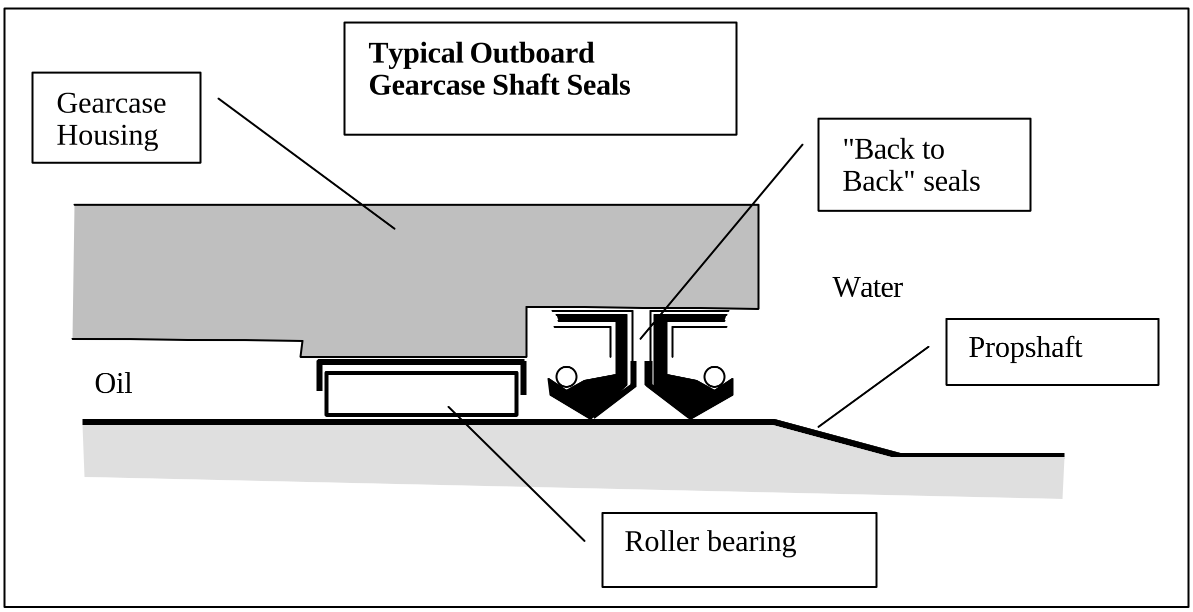
Stevens Gearcase Pressure or Vacuum Tester

Gearcase pressure and vacuum testers are essential tools in any outboard workshop. They are simply a hand pump with one way valves and a pressure gauge. You need BOTH because most modern gearcases use double lip seals (or two seals installed back to back) so that one seal lip keeps the oil in and the other keeps the water out. Depending on boat speed and gear oil temperature the higher pressure can be either inside or outside of the gearcase, so double lip seals are required. The pressure tester tests the function of the inner seal lip, O rings and gaskets (keeping the oil in), while the vacuum tester tests the function of the outer seal lip (keeping the water out).

Drain the oil, put one of the oil plugs back in and your gearcase pressure tester in the other oil plug hole. Pump the tester up to 20-40 kPa (3-6 psi) and watch the gauge. If the pressure drops at all, submerge the gearcase in water and follow the bubbles to find the leak. If pressure holds at this level, pump it up to 110-120 kPa (16-18 psi) and again check for leaks. The two pressure levels are required to check all likely possibilities. A tiny crack in the housing or a damaged O ring requires fairly high pressure to really show up the leak, however, worn seals are more likely to leak at low pressures, because higher pressures can actually force them onto the shaft and give a false good reading.

If the gearcase passes the pressure test, repeat the two step dose, but this time with the vacuum tester. Obviously a leak here that did not show up during the pressure test can only mean one of the outer seal lips is the culprit.

What if both pressure and vacuum tests don't find a leak, but there's still water in the oil? It this possible? Yes. One problem that will definitely cause water entry, but will pass the static pressure and vacuum tests is a bent drive or propeller shaft. This is because the lip seals can't stay on the shaft surface once the rpm is up.



Metal in the oil

If there's only a little water in the oil and you can fix the leak without completely dismantling it, then most technicians will just fix the leak and change the oil. They know that a small amount of water can mix with the oil and not impair its lubricating or rust preventing qualities.

But metal in the oil is different. Most oil drain plugs today have a magnet and they always have some "fur" attached when removed. Tiny dust sized specs of metal come off the gears and dog clutch during normal operation and attach to the magnet, this is normal. If you can rub some of the "fur" from the magnet between your finger tips and it disappears, that's also normal. If there are lumps in it, and/or the oil comes out with an silver or gold coloured metallic streaks through it, you've got a problem. Not only is one of the gears or the dog clutch is trouble, but all those metals pieces have been circulating through the bearings, so don't forget these. (note the Archimedes Screw like a big thread on the lower end of the driveshaft in the picture. That pumps the oil up to the upper driveshaft bearings and ensures circulation throughout the gearcase).

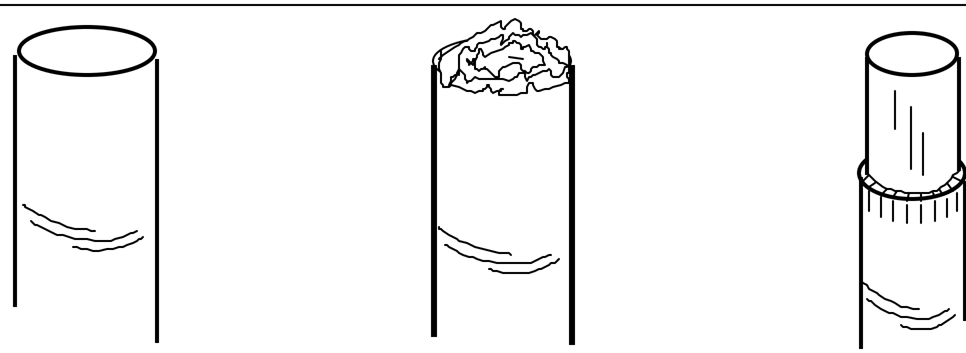
Shafts

Most large outboard drive and propeller shafts are made in two pieces, sometimes welded together so they look like a single piece. This is because that portion inside the gearcase needs to be very hard for the roller bearing surfaces, while that portion exposed to the elements needs to better resist corrosion. So inside the gearcase you have a high carbon, hardened steel shaft while outside it's usually a 400 or 600 series stainless steel. These types of stainless steel will commonly get a small amount of surface rust in a marine environment, but have the strength to handle large engine power without being huge. The two pieces are pressed, splined or friction welded together.

Bent shafts come about from a variety of reasons, with the most common ones being when the propeller strikes a hard underwater object (rocks, concrete) or if the propeller hits the wall when backing your rig into the garage. The chances of straightening a two piece welded shaft (most propshafts are this type) without leaving some tiny surface imperfections that can later develop into cracks, is very remote so it's usually not worth the risk.

Broken shafts are a different proposition. Here the types of stainless steels used have some interesting properties that can help technicians diagnose and fix the cause. Basically there are two types of break cause, a sudden impact or a somewhat slower fatigue failure from repeatedly bending the shaft. The broken surface will show a quite different appearance depending on which cause is involved.

An impact failure is when one end of the rotating shaft is suddenly stopped. This leaves a very smooth break, looks rather like the shaft was cut in a lathe. Impact failure can be caused by striking an underwater object, wrapping a rope around the prop at high speed, selecting two gears at once (usually only possible with electric shift gearcases), jumping out of gear, or even a severe engine misfire. Anything that causes very sudden and high torsional loads in the shaft.



Smooth break -
- Impact failure

Jagged break -
- Misalignment failure

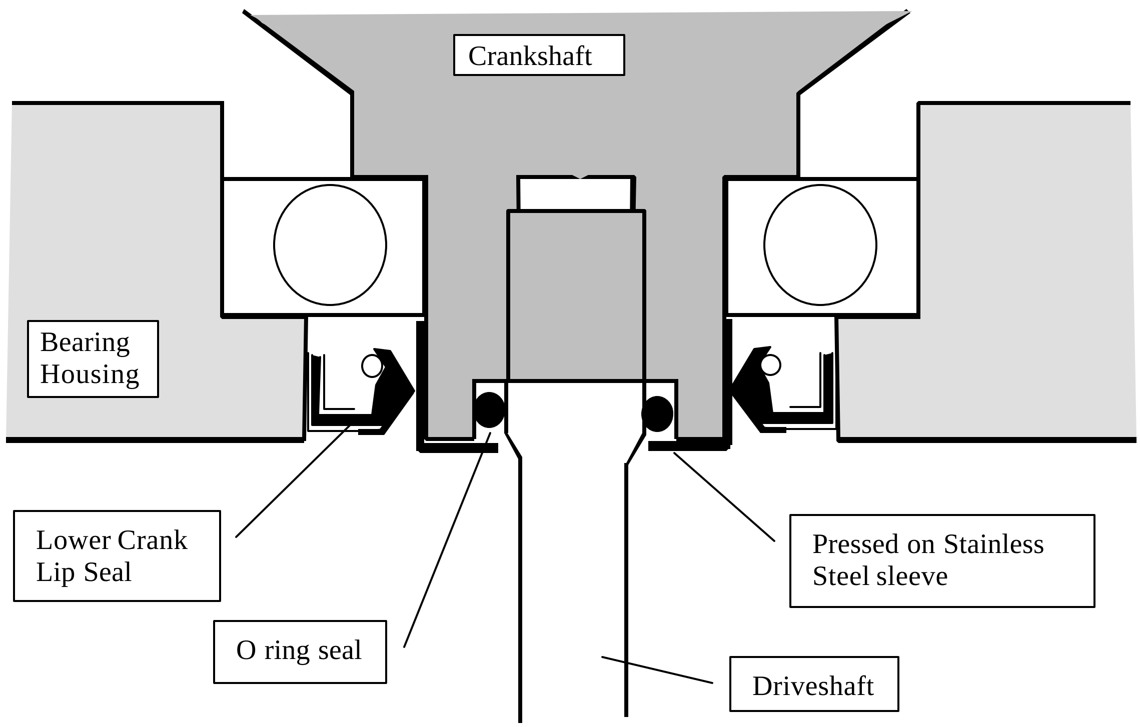
Splines worn away -
- Misalignment failure or
- Water entry

A fatigue failure on the other hand starts with tiny cracks on the surface of the shaft as it is repetitively bent, which then get bigger and bigger there is not enough shaft left to carry the load and the remainder breaks. Because the failure starts from lots of little surface cracks that all grow in different directions, much of the break surface will be jagged and uneven (except perhaps for the last portion to fail). Fatigue failures are caused by misalignment that is each end of the shaft is not on the exact same centre line. Common causes of misalignment are bent housings, loose bolted joints, or missing alignment dowel pins.

Misalignment can also cause rapid spline wear in applications where the misalignment may not be severe enough to cause breakage. This is because there is some sliding movement at splined joins each time the shaft rotates.

Another very similar cause of rapid spline wear is rust. This occurs where driveshafts (stainless steel) spline into crankshafts (very hard high carbon steel). If any water gets into this joint, the resulting rust on the inside of the crank splines provides a rough, abrasive surface that will then wear away the much softer stainless steel driveshaft. This area can only be lubricated when the gearcase is off the engine and most manufacturers specify a high temperature, high pressure lube like a high molybdenum content grease. However, even the best lubricant is no match for a rusty shaft if water is allowed to get in.

This splined drive to crank shaft joint is normally well above the static water line and sealed with O rings or a lip seal, so water normally has great trouble in getting in. However, if you find a rig where the static water line is too high (where you also risk getting water into the lower cylinders through the exhaust ports) or the seals are missing or damaged, then worn away driveshaft splines will be the result. When this happens you must replace BOTH shafts, to fix the problem. Replacing just the driveshaft can sometimes feel OK, but because the internal crank splines are smaller than original size (rusted away) it will only be a temporary repair.



Details of a typical crank to driveshaft splined joint. Correct lubricant on the splines and checking the condition of seals should be part of every service where the gearcase is removed.

Case Study 1

The commercial fisherman's 40 HP had a broken driveshaft, right at the O ring groove near the upper splines. This engine was several years old and used every day, so it had done hundreds, if not thousands, of hours, a reasonable life for driveshaft except this was not the original. In fact it was only about a month old, and the original had suffered exactly the same fate. It looked very suspiciously like there was something wrong with this engine that was leading to shaft failure.

The trouble was, the technician could not find it. Both broken shafts had the same smooth surface at the break indicating an impact type failure. Just to be sure he'd checked for bent shafts, bent housings, misalignment between housings, loose joints, warped flanges and so on, but without any luck. This engine looked just like all those others out there that don't break shafts.

Maybe it was something to do with the way the fisherman drove? Only one to find out, so a ride was arranged with the owner as soon as the new shaft was fitted. All went well until they were well outside the marina and the fisherman opened it up to nearly full throttle. After a few seconds there was a series of engine misfires that were quite noticeable all through the boat. The fisherman also noticed and pulled the throttle back just a little. The misfires reduces to just an occasional one every few minutes.

The technician asked, "How long has it done that?" The answer came back "Oh, about 2 or 3 months. I don't worry about it much, because it only happens sometimes and if I pull the throttle back, it stops".
The technician then explained "this is a large two cylinder engine, so there are relatively large gaps between each power pulse. The misfires make that gap much larger, but randomly so there is quite a lot more torsional loads going into the driveshaft. That could be why we have broken two shafts"

Back at the shop an examination of the ignition system showed some very rusty steel spring terminals where the high tension wires attached to the spark plugs. On this flywheel magneto ignition system that was enough to drop the available voltage below what is required at high power, hence the misfires. A few dollars worth of plug terminals (and decent rubber boots) cured the misfires and more importantly the driveshaft breakages.

Case Study 2

The 20 HP outboard powerhead was lying upside down on the bench. Technicians were peering at the lower end of the crankshaft. Specifically, at the splines where the driveshaft attaches. This engine had just worn all the splines off the upper end of the driveshaft.

The crank splines looked OK, and they still fitted well with a new shaft. Nothing looked wrong here. The driveshaft was the right part number and length. Comparing old and new parts also showed no differences.

Perhaps the midsection was bent? If the alignment of the shaft is such that both ends are not exactly in line, then the slight bending that occurs with each rotation of the shaft eventually leads to a fatigue failure or rapid wear at any slip joint. Splines are a slip type joint so rapid wear could be from misalignment.

The midsection housings were checked, but found within spec. Nothing was wrong there. Then while cleaning up the bottom surface of the powerhead, the technician noticed a step in the gasket surface. This was not right. When all the old gasket was scrapped off, he could then see that the crankcase was not in line with the block.

The powerhead had been recently rebuilt and when the crankcase was refitted, the locating dowel had been left out. This does not seem much of problem because the outer races of the crankshaft main bearings serve to line up the crankcase horizontally so a dowel is not required here, however vertical alignment (parallel to the crank main bearing line) is a different matter.

On this powerhead the crankcase was about 0.7 mm (0.030") out of line, which meant the gasket surface along the bottom of the powerhead (where it meets the midsection) was no longer flat. That results in the powerhead no longer being in line with the driveshaft and each with rotation the splines on the driveshaft had been moving in and out of the crank. Only a small amount, but many thousands of cycles happen over a short period of time (at crankshaft speed), so the wear is rapid.

And so it proved with this engine. Once the crankcase was correctly aligned, with the dowel pin in place, and a new shaft fitted, there was no more rapid spline wear problems.

Case Study 3

The V4 140 HP outboard powerhead was spread across the bench. A group of technicians and the outboard manufacturer's rep were pouring over the bits. Lots or frowns were being exchanged because this engine had had a distinct and loud knocking noise, but there were no faulty engine parts to be seen.

All the bores, pistons, crank journals, wrist pins, bearings and so on, not only looked almost as good as new, they measured up OK too. Just in case they had missed something, all parts had been measured and inspected a second time, but it was still the same.

"This powerhead is OK" said the rep.
"But it definitely had a loud knock" said the technician "there's got to be something wrong in there".
"Well" said the rep "it's not in here, where's the rest of this rig, lets look there and see if anything else is out of place".

Outside in the yard, the midsection and lower unit were still attached to the boat. Externally everything looked fine no damage was visible. "Have you checked the gear oil?" asked the rep. "sometimes a gear problem can sound just like something wrong inside the powerhead".

A clean container was found and the gear oil drained. The oil came out a funny silvery colour and the drain plug magnet had what looked like several small metal chips stuck to it. There were also several visible chips in the oil. Something was wrong in here.

Dismantling the gearcase showed one complete and several partial teeth broken off the pinion gear. This looked like it could be the culprit, but some of the technicians were skeptical. How could a broken gear, down in the gearcase (which is under water) sound like an internal powerhead problem?

The pinion gear rotates at crankshaft speed while ever the engine is running and the noise generated by the missing tooth can be transmitted through the lower unit and midsection housings so that it sounds like the problem is above the water. And so it proved in this case.

When the engine was reassembled with new gears (plus the gearcase bearings damaged by metal chips in the oil) and some new powerhead gaskets (all the other powerhead parts went back) it was "as quite as a new one" and performed like one too.